Proceedings of the American Academy of Arts and Sciences.

Vol. XLVIII. No. 16. — March, 1913.

CONTRIBUTIONS FROM THE PHANEROGAMIC LABORATORIES OF HARVARD UNIVERSITY. — No. 59.

CRETACEOUS PITYOXYLA FROM CLIFFWOOD, NEW JERSEY.

By Ruth Holden.

With Four Plates.

CONTRIBUTIONS FROM THE PHANEROGAMIC LABORATORIES OF HARVARD UNIVERSITY.—No. 59.

CRETACEOUS PITYOXYLA FROM CLIFFWOOD, NEW JERSEY.

By Ruth Holden.

Presented by E. C. Jeffrey. Received December 1, 1912.

During the spring of several successive years, Dr. E. C. Jeffrey collected a considerable amount of lignite from the Middle Cretaceous of Cliffwood, New Jersey, which he has since turned over to the writer for investigation. The material was from two localities,— that from the yards of the Cliffwood Brick Company, and that from Cliffwood Beach. The former lot was as a whole badly pyritized and of no value from a structural standpoint; while the latter was often perfectly preserved, revealing all the details of its structure under microscopical examination. The greater part was found to belong to the genera *Cupressinoxylon*, *Araucarioxylon*, and *Brachyoxylon*, and will be described later. There were also specimens representing three types of *Pityoxylon;* the characteristics and affinities of which it is the purpose of this paper to discuss.

Pinus protoscleropitys n. sp.

It will be appropriate to begin with the one which most closely resembles modern forms. Figures *a*, *c*, and *e*, Plate 1, reveal the general features of the lignite in question. It will be noticed that the tracheides are small and thick walled. The summer elements are few in number, but limit a well marked annual ring, as shown in the lower part of Figure *a*. Resin ducts such as are characteristic of all *Pityoxyla* occur in two planes. Figure *a* includes two vertical canals, and to the right a horizontal one. It is apparent that both are completely filled with tyloses,— a condition more clearly seen in Figures *c* and *e*. Surrounding each, there is a jacket of epithelial parenchyma. The cells composing this jacket are thin walled, heavily pitted, and in general devoid of contents. Figure *d*, on the other hand, illustrates a case where they are filled with a dark, resinous substance. Figure *b* gives the topography next the pith,— at a lower magnification. It will be noticed that, as in the hard pines, there is a double series of

resin ducts in the first annual ring, but the inner series in this case lies in the primary wood. This condition is at variance with that of hard pines where both are in the secondary wood. The presence of resin canals in the primary wood is not unparalleled in the coniferous series, — they occur in the primary wood of the root of all the Abietineae (1), of the cone axis of *Sequoia gigantea* (2), and of certain members of the Araucarineae (3). True medullary canals, such as have been described in *Pinus succinifera* (Goepp) Conw. (4) seem to be entirely absent. In the succeeding annual rings, the vertical canals are smaller and less frequent. With the horizontal canals they form a freely anastomosing system (Figure *c*).

Figure *b* also shows the character of the pith. Scattered among the thin walled parenchyma cells there are clusters of very thick-walled sclerified elements. Such a cluster occurs in the upper part of Figure *b*. These show a tendency to be in more or less definite horizontal bands, but do not form true diaphragms.

The medullary rays are of two sorts,— linear and fusiform. The latter are frequent, and always embrace a resin canal (at the left of Figure *e*), a leaf trace (Figure *f*) or both. The linear rays are much more abundant, as may be seen in any of the illustrations. They are usually low, and as in living pines, destitute of resinous content. The walls are thin and heavily pitted. The lateral pits, as shown in Figures *a* and *b*, Plate **2**, vary from one to two to each cross field; they are small, the mouths lenticular on the wall of the ray and circular on that of the tracheide. Not infrequently there are indications of fusion where two small pits unite to form one of medium size. At the extreme lower right of Figure *a*, and in the upper part of Figure *b*, such phenomena are represented. The resulting pore is rarely as large as in modern pines such as *Pinus strobus*, though occasionally a single pit occupies almost the entire cross field, as in the lower left of Figure *b*. Both horizontal and end walls are also heavily pitted.

In association with this parenchyma, there are longer and lower cells, always devoid of contents, with bordered pits on lateral, horizontal and end walls. That these are ray tracheides, such sections as are photographed for Figures *c* and *d*, prove beyond question. They may occur only on one margin of a ray, or on both, as in Figure *c*. Rarely they are interspersed, with parenchyma above and below. Projecting in from the horizontal walls, there are well marked teeth. These may be seen in the lower ray tracheide of Figure *c*, the upper one of Figure *d* and better in Figure *e*. These teeth are doubtless analogous to similar appearances in hard pines, though less developed

than is usually the case in the latter? Aside from our specimen, there are but two instances where ray tracheides have been described in a fossil,— *Pinus scituatensiformis*, Bailey (5) and *P. succinifera* (Goepp.) Conw. (4). In the former, the walls seem to be smooth like those of living soft pines, while in the latter, Conwentz figures just such a sculptured appearance as is presented by the lignite under consideration.

The pitting of the tracheides is entirely confined to the radial wall. Owing to the small size of the elements, the pores are usually uniseriate. They are normally circular in outline and scattered; rarely toward the end of a tracheide, they become closely approximated and flattened by mutual contact. Figure *d*, Plate **1**, represents a typical condition. In the larger tracheides of the spring wood, the pores are often diseriate. In such instances they are always opposite and separated by well marked "bars of Sanio." In the living condition these bars are formed by the thickening of the cellulose middle lamella, which in the process of fossilization, rots away, leaving an empty space. Consequently the bar appears as a white line. A particularly favorable region is shown in Figure *f*, Plate **2**. Were anything more needed to demonstrate the Abietineous affinities of our lignite, these would suffice, since as shown by Miss Gerry (6) these bars of Sanio are invariably absent in woods of Araucarian affinities.

The short shoots in this fossil are much larger than those in most living pines, though never showing annual rings as in *Ginkgo*, Figure *c*, Plate **4**, represents one of these organs. On careful examination it may be seen that there is a single row of resin ducts in the wood, and that the medulla contains sclerotic nests similar to those of the main axis. This section was cut at some distance from the pith. Figure *d*, Plate **4**, shows, at a lower magnification, a section cut considerably nearer the centre. In the upper part of the photograph the short shoot may be seen; toward the lower limit, there is a dark spot. Figure *f*, Plate **1**, represents this spot at a much higher magnification, and demonstrates its foliar nature. Examination of serial sections has shown that at its departure from the medulla, each brachyblast is subtended by an axillating leaf trace, which dies out after a few years, leaving an apparently unaxillated short shoot. A similar condition has been described by Dr. Jeffrey in the case of *Woodworthia*, an Araucarian from the Triassic (7): in *Woodworthia*, however, these short shoots often branch, which is never the case in this *Pityoxylon*. The short shoot of *Ginkgo* is always axillated, in this case by a double leaf trace; in *Larix* also the short shoots are axillary structures. In the majority of living pines,

however, such is not the case. That the primitive condition was for the brachyblast to be subtended by a leaf trace, is further indicated by the occasional presence of an axillating strand in the seedling of certain living pines, — e. g. *Pinus strobus*, and in the mature wood of certain others,— e. g. *Pinus Jeffreyi*. The character of the short shoot thus presents an interesting example of seedling recapitulation. The leaf traces of this *Pityoxylon* are not confined to an axillating position, but are quite numerous near the pith. Their presence would indicate that the leaves of this conifer were of two sorts,— those borne directly on the main axis as in the seedling of living pines, and those on short shoots. Such a condition has been figured by Fontaine (8) in *Leptostrobus*, Heer. The foliar strands are jacketed by parenchyma, the whole forming a fusiform ray (Figure *f*). Not infrequently a resin duct accompanies them in their outward journey,— a condition comparable to that of the vegetative leaves of some of the Abietineae, and of the sporophyll traces of some of the Araucarineae (3).

Having described the salient features in the anatomy of this specimen, it remains to consider its affinities. The presence of resin canals in two planes relegates it at once to the genus *Pityoxylon*, Kraus, and the short shoots narrow its possibilities to *Larix* and *Pinus*. There are a number of reasons for excluding the former,— dentate ray tracheides, thin-walled ray parenchyma, with fusion pits, abundant tylosed resin canals,— none of which occur in the wood of the larch. Further *Larix* has wood parenchyma at the end of the year's growth and tangential pits,— both of which are absent here. It seems clear therefore that our lignite belongs to the genus *Pinus*. Pines may be divided into two great groups,— hard and soft. Aside from certain external criteria,— for the most part unreliable,— the two groups may be differentiated by the following characters. Hard pines have sculptured ray tracheides, two or more rows of resin canals in the first annual ring, sclerified pith (except most of the two-needled varieties) and lack tangential pitting (except in the first few year's growth and the cone axis). Soft pines on the other hand, have smooth walled ray tracheides, a single row of resin canals in the first annual ring, tangential pitting, and lack stone cells in the pith. On all four of these features, our lignite belongs with the hard pines, and since it is the earliest known completely differentiated hard pine, we propose for it the name of *Pinus protoscleropitys*. In using the generic name *Pinus* rather than *Pityoxylon*, we are following the example set by Conwentz and Bailey, since the specimen in question cannot be separated anatomically from living pines.

It is of interest to compare this type with other fossil pines. The only ones described up to now with ray tracheides are *Pinus scituatensiformis*, Bailey (5) and *P. succinifera*, Conw. (4). First let us consider the former, since it is of the same geological age as our specimen. Both have a sclerified pith, large short shoots, and tyloses in the resin canals. *P. situatensiformis* differs from the lignite described in this article in numerous features,— the ray tracheides are smooth walled, the rays and abundant epithelium of the vertical canals are highly resinous, the lateral pits of the rays are small and invariably one per crossfield, the summer tracheides are pitted on their tangential walls, and the short shoot has no axillating leaf trace. While our specimen is a typical hard pine, that described by Mr. Bailey unites the characteristics of both groups,— it has the tangential pitting and smooth ray tracheides of a soft pine, with the sclerified pith of a hard. It seems to be a more generalized type, perhaps representing an ancestral condition before the two groups had become sharply separated.

With *P. succinifera* of the early Tertiary, our lignite has more in common. Both have sculptured ray tracheides in marginal and interspersed positions; thin-walled, non-resinous ray parenchyma; septate tracheides around the resin ducts, which are surrounded by thin-walled heavily pitted epithelium and filled with tyloses. On the other hand, as opposed to our specimen, *P. succinifera* has but a single row of resin ducts in the first annual ring; tangential pits; tyloses in the tracheides; ray cells with sometimes four small piciform pits to each crossfield, sometimes one large fusion pit; resin canals embedded in the pith, and no stone cells. Further, ray tracheides in *P. succinifera* do not occur normally in the first few years' growth, while in our form they are present in the first annual ring.

From this comparison of *P. protoscleropitys* with other similar *Pityoxyla* it is evident that the former represents a higher and more specialized type than either of the others. It has all the features of a living hard pine, while the others present different combinations of the features of both hard and soft. The occurrence of a completely differentiated hard pine as far back as the Middle Cretaceous substantiates the conclusion reached by Jeffrey (9) from a study of the leaves that the two groups had already become separate by the Middle Cretaceous. Zeiller's description of cones of both groups from the Jurassic renders it probable that the separation goes back to that epoch. An interesting corollary to the presence of such a modern type of wood in the Cretaceous is afforded by the modern character of the leaves of Upper Cretaceous pines described by Stopes and Kershaw (10).

These facts indicate that the Abietineae are a much older group geologically than is usually supposed. It is further evident that such forms as these must be the ancestors of living pines, and that such forms as *Pinus scituatensiformis* and *P. succinifera*,— of the same or later geological age, yet less specialized,— are off the main line of development.

Before leaving this specimen, it is convenient to consider the light it throws on the origin of ray tracheides. Jeffrey and Chrysler (11) concluded that ray tracheides were evolved during the early Tertiary, basing their conclusions on the following developmental and palaeobotanical evidence. Ray tracheides are absent from the cone axis of most modern pines, and poorly developed in the seedling; they are absent in *Pinites Ruffordi*, Seward (12) (Wealden), *Pityoxylon statensense* and *P. scituatense* (Middle Cretaceous) and do not appear for several years' growth in *Pinus succinifera* (Early Oligocene or Late Eocene). The discovery of ray tracheides in *P. scituatensiformis* (Middle Cretaceous) led Mr. Bailey to the conclusion that these structures came in during the Middle Cretaceous. In that species they do not appear at all in the first ten to fifteen years' growth and thereafter are but poorly developed. Their occurrence, though rare, in the first annual ring of *P. protoscleropitys* (Middle Cretaceous) and their abundance later, seems to indicate that they are a more ancient feature than has been assumed by any of the above cited investigators. It is probable that they were developed in the Lower Cretaceous if not in the Jurassic.

As regards the origin of ray tracheides, the final word remains to be said. There are two theories which have been advanced to explain the question. Thompson (13) has suggested that tracheary ray cells are derived from vertical tracheides, which by progressive shortening, have taken on a horizontal position. Stages in such a process he found in *Pinus resinosa* and *P. strobus*. As Bailey pointed out there are two objections to this theory,— if these phenomena are recapitualtionary or reversionary, in the first place, why are they more evident in these highly specialized varieties than in such primitive ones as the Nut and Foxtail pines? And, in the second, why are they completely absent in fossil forms? Mr. Bailey was unable to find any trace of such an origin in *P. scituatensiformis*, and I have been unable to find any in *P. protoscleropitys*. Since there is no confirmatory evidence in the case of the primitive living forms, or the two oldest known fossil forms, it seems improbable that Mr. Thompson's interpretation is correct.

On the other hand, Penhallow (14) has suggested that they have been formed from ray parenchyma by a thickening of the cell wall. As Bailey points out, the evolutionary sequence has been from thick- to thin-walled parenchyma, not *vice versa*,— a consideration which immediately invalidates this hypothesis.

Pityoxylon foliosum n. sp.

The next specimen to be considered is much less like modern forms than that just described. Figures *a* and *b*, Plate **3**, represent at different magnifications cross sections of the wood. As may be seen in Figure *b*, the annual rings are very broad and well marked,— the first occurring near the lower limit of the field. Another appears a little below the centre of Figure *a*. There are many concentric arcs extending half way or more around the stem, caused by some external pressure in the process of fossilization. One such is shown in the upper part of Figure *a*. That it is not a true growth ring is proven by the fact that it does not completely encircle the medulla, and that the tracheides composing it are not pitted on the tangential wall,— an invariable characteristic of the summer tracheides of the lignite in question.

Resin ducts are very numerous, extending in two planes,— vertical and horizontal. The vertical canals are surrounded by clusters of highly resinous epithelial parenchyma. Not infrequently a single mass contains three or even four tangentially grouped canals, which as may be seen from longitudinal sections, intercommunicate. The epithelium is moderately thick-walled, and densely perforated by simple pits. The horizontal canals are also numerous, as shown by Figure *e*. Together with the vertical canals they form a freely anastomosing system of resin passages throughout the wood. Both horizontal and vertical canals, especially the latter, are almost invariably filled with thick-walled tyloses. At the extreme right of Figure *b* the proximity of the canals to the pith may with difficulty be ascertained. Figure *d*, a radial longitudinal section, shows the relation more clearly. In fact the canals are often so near to the medulla that in transverse section they appear to be embedded in it. A more careful examination however, reveals the presence of a jacket of metaxylem elements around the duct. This occurrence of canals in the primary wood is unknown in the main axis of living pines, but is similar to that of *Pinus protoscleropitys*.

Toward the right of Figure *b*, a vascular strand may be seen to pass

off from the medulla; Figure *c* shows one of these leaf traces in cross section. Such leaf traces are quite abundant in this specimen, but in the limited amount of material available, there was a complete absence of short shoots,— a remarkable condition for an obvious *Pityoxylon*. The trace appears to be always single, like those of the fascicular leaves of all living pines, at the point of departure from the pith. Further, like those traces the xylem is entirely centrifugal. Not infrequently a resin canal accompanies the strand in its outward passage, rarely two.

The rays are of two sorts,— linear and fusiform. The latter are very numerous; they consist of parenchymatous elements embracing a resin duct, a foliar trace, or both. The character of the linear rays may be inferred from the photomicrographs. They are low and highly resinous; the walls are comparatively thin and heavily pitted. The lateral pits are usually one to each cross field, rarely two: they are piciform, with an elliptical opening on the side of the ray and a circular one on that of the tracheide. Unlike living pines, all the cells composing the ray are parenchymatous, although those on the margin are often quite different from the others, being irregular in shape and destitute of resinous content. Figure *c* shows several instances of this condition. At first sight they appear to be ray tracheides, but the unbordered character of the pits negatives that possibility.

The tracheides are uniformly small and thick-walled. The pits on the radial wall are uniseriate and scattered; in places, indications of the so called "bars of Sanio" could be distinguished, but as a rule the indifferent state of preservation obscures this feature. In the majority of cases, the pits are confined to the radial walls, but those tracheides laid down at the end of the year's growth, have pores also on the tangential wall. As is well known, this is characteristic of all the Abietineae except hard pines.

The characteristics of the pith are evident from Figures *b* and *d*. There are two sorts of elements,— thin-walled parenchyma and thick-walled sclerenchyma, the latter standing out as black masses in the photographs. They show a general tendency toward arrangement in horizontal bands, which are not, however, sufficiently localized to form diaphragms.

It remains now to consider the affinities of this lignite. The presence of resin ducts in both horizontal and vertical planes affiliate it with the genus *Pityoxylon*, Kraus. Like all previously described Cretaceous *Pityoxyla* (with the exception of *Pinus scituatensiformis* and possibly *Pinus Nathorsti* Conw. (15), about which however it is

impossible to tell, owing to imperfect preservation), the rays are devoid of tracheides, and bear out the conclusion of Jeffrey (11) that the majority of pines of this horizon had not yet acquired them. The affinities of this specimen must, therefore, lie with one of the four Abietineous genera normally possessing resin canals,— *Pinus*, *Picea*, *Larix* and *Pseudotsuga*. Both the last two have well marked wood parenchyma at the end of the year's growth. Since this feature is lacking in our fossil, it cannot be related to them. Between *Pinus* and *Picea*, there is little occasion for hesitation. The abundant, tylosed resin canals, complete absence of spiral thickenings, thin-walled parenchyma forming the epithelium of the canals and the cells of the medullary rays, clearly indicate its connection with *Pinus*. Another criterion for distinguishing the wood of *Pinus* and *Picea* is the wound reaction. As pointed out by Jeffrey (1) dense tangential series of resin canals are an invariable concomitant of injury in the case of *Picea*. One fragment of the lignite under consideration had a large wound cap. This was carefully examined, but no trace of traumatic canals found. That the capacity for such a reversion had been acquired as early as the Cretaceous, is proved by the presence of a traumatic series in *Pinites Ruffordi* (12) from the Wealden of England. If our fossil were related to *Picea*, as severe a wound as it had received would have unquestionably stimulated this characteristic reaction. Against this proposed affiliation with *Pinus*, may be brought forward the absence of short shoots. Fontaine (8) however, has described from the Potomac certain coniferous remains with both fascicular leaves on lateral and terminal short shoots, and also primary leaves, borne directly on the main axis, which are spirally arranged like those of seedling pines. In view of the small amount of available material, it is entirely possible that our specimen really possessed typical short shoot organs. Jeffrey (9) has suggested that *Prepinus* may belong with this *Leptostrobus* of Fontaine's. If such is the case, the lignite under discussion may be referred to *Prepinus*. Its characteristics are, indeed, extremely like those of the wood of the brachyblast of *P. statenensis*. Both have sclerified nests in the pith, resin canals in two planes, highly resinous rays with piciform lateral pitting and tangential pitting of the tracheides. On the other hand, there are certain important differences. Modern pines may be divided into the two classes,— hard and soft. Disregarding the differences in ray tracheides, the characteristics of the two are,— first, hard pines have a double, soft,— a single, leaf trace (in both, however the trace leaves the wood of the brachyblast as one and divides in the cortex); second,

hard pines have two or more rows of resin canals in the first annual ring,— soft but one; third, hard pines (except most of the two needled varieties) have stone cells in the pith,— soft have none; fourth, hard pines have not, soft have, tangential pitting of the summer tracheides. Our lignite, then, is nearer the hard than the soft pines, having more than a single row of canals in the first annual ring, and stone cells, but it has also the tangential pitting of a soft pine. On the other hand, *Prepinus statenensis* has the sclerified pith of a hard pine, with the single leaf trace of a soft. Moreover, it has tangential pitting, and but one row of resin canals. It must be borne in mind, however, that we have to do with a brachyblast, and that the second row of resin ducts may be omitted for lack of space. This condition of affairs would be analogous to that of many living hard pines, where, as *Pinus rigida*, there may be but one row of canals in the short shoot, and sometimes none at all in the first annual ring of the seedling. The fact that the leaf trace of *Prepinus statenensis* is mesarch, whereas that of our specimen is endark, need not militate against this suggested relationship. In the first place, we have a record of only the fascicular leaves of *Prepinus*, and of only the primary leaves of this lignite: — there are no grounds for assuming that they must have been alike in this respect. In the second place, it is entirely possible that the strand, though endark in the wood, might acquire mesarch structure in the cortex, or even in the blade of the leaf. An analogous condition is true in the case of the Cycads. Any connection between our specimen and *Prepinus viticetensis* (16) is less likely, because even though the latter has two rows of resin canals, it lacks the highly characteristic medullary stone cells. The identification of this lignite with the wood of *Prepinus*, or with either *Leptostrobus*, Heer or the somewhat similar *Pinites Solmsi* (17) of Seward,— both of which are known only superficially,— must remain very problematical.

Its relation to other *Pityoxyla* should next be considered. As regards other lignites from Cliffwood, it differs from *Pinus protoscleropitys* in the absence of ray tracheides; and from *Pityoxylon hollicki* Knowlton (18) in that the latter has 'punctations contiguous,' 'thick-walled ray cells,' and often two series of pits. Thickness is, of course a relative term, and more material of our specimen might show diseriate pitting. However, Knowlton states that the structure is 'too obscure for accurate description,' so further comparison is impossible. The lignite in question differs from *Pinoxylon dacotense*, Knowlton, in that the latter has only vertical canals, and from *Pityoxylon statenense* in that the latter has no stone cells in the pith. Further, it can-

not be identified with *Pinites Ruffordi* which has tyloses in the tracheides and teeth in the ray parenchyma. One character absolutely puts *P. Ruffordi* out of the question,— it contains traumatic resin ducts,— which as pointed out above, were not present here. It cannot be placed with *Pinus Nathorsti* (15), which had thick-walled, unpitted parenchyma around the resin canals and lacked tangential pitting, or with *Protopiceoxylon antiquius* Gothan (19). That species had thick-walled ray parenchyma, thick-walled epithelium around the resin canals, three to four pits to each crossfield on the lateral walls of the rays, and lacked tangential pitting,— features diametrically opposed to those of our fossil. Accordingly, our specimen cannot be identified with any previously described. In view of the fact that the leaves were borne on the main axis exclusively, rather than on short shoots, it may appropriately be called *Pityoxylon foliosum.* The only other forms with such leaves are *Pinus protoscleropitys* and *Prepinus.* With the former it cannot be identified because that form had such abundant short shoots that it would be impossible to miss them, and further it had ray tracheides. As suggested above, it may very probably be the wood of *Prepinus.*

Pityoxylon anomalum n. sp.

The third type of Pityoxylon differs from either of those previously described, though similar to *P. foliosum.* Figure *f*, Plate **3**, shows the general topography of the stem. The annual rings are narrow and indistinct. Resin ducts are present, extending in two planes, but as is evident from a comparison of Figures *b* and *e*, Plate **3**,— equally enlarged — they are much less frequent in this specimen than in the former. A further difference is that there is but one row in the first annual ring; this row occurs in the primary wood. Figure *a*, Plate **4**, shows the character of the ducts. They are surrounded by a large mass of epithelium, which is completely filled with resin. This feature is best brought out in the longitudinal sections (Figures *b*, *f*, and *g*). The cells of this jacket are fairly thin-walled, and very heavily pitted, which doubtless accounts for the abundant tyloses, which are very thick-walled. As a rule there is but a single canal in each cluster of parenchyma,— rarely there are two.

The tracheides are badly collapsed, and the lumen usually completely obliterated. At times, however, in the better preserved regions, the characteristics of the pitting may be made out. In the lower part of Figure *g*, for example, a single row of pores may be ob-

hard pines have two or more rows of resin canals in the first annual ring,— soft but one; third, hard pines (except most of the two needled varieties) have stone cells in the pith,— soft have none; fourth, hard pines have not, soft have, tangential pitting of the summer tracheides. Our lignite, then, is nearer the hard than the soft pines, having more than a single row of canals in the first annual ring, and stone cells, but it has also the tangential pitting of a soft pine. On the other hand, *Prepinus statenensis* has the sclerified pith of a hard pine, with the single leaf trace of a soft. Moreover, it has tangential pitting, and but one row of resin canals. It must be borne in mind, however, that we have to do with a brachyblast, and that the second row of resin ducts may be omitted for lack of space. This condition of affairs would be analogous to that of many living hard pines, where, as *Pinus rigida*, there may be but one row of canals in the short shoot, and sometimes none at all in the first annual ring of the seedling. The fact that the leaf trace of *Prepinus statenensis* is mesarch, whereas that of our specimen is endark, need not militate against this suggested relationship. In the first place, we have a record of only the fascicular leaves of *Prepinus*, and of only the primary leaves of this lignite: — there are no grounds for assuming that they must have been alike in this respect. In the second place, it is entirely possible that the strand, though endark in the wood, might acquire mesarch structure in the cortex, or even in the blade of the leaf. An analogous condition is true in the case of the Cycads. Any connection between our specimen and *Prepinus viticetensis* (16) is less likely, because even though the latter has two rows of resin canals, it lacks the highly characteristic medullary stone cells. The identification of this lignite with the wood of *Prepinus*, or with either *Leptostrobus*, Heer or the somewhat similar *Pinites Solmsi* (17) of Seward,— both of which are known only superficially,— must remain very problematical.

Its relation to other *Pityoxyla* should next be considered. As regards other lignites from Cliffwood, it differs from *Pinus protoscleropitys* in the absence of ray tracheides; and from *Pityoxylon hollicki* Knowlton (18) in that the latter has 'punctations contiguous,' 'thick-walled ray cells,' and often two series of pits. Thickness is, of course a relative term, and more material of our specimen might show diseriate pitting. However, Knowlton states that the structure is 'too obscure for accurate description,' so further comparison is impossible. The lignite in question differs from *Pinoxylon dacotense*, Knowlton, in that the latter has only vertical canals, and from *Pityoxylon statenense* in that the latter has no stone cells in the pith. Further, it can-

not be identified with *Pinites Ruffordi* which has tyloses in the tracheides and teeth in the ray parenchyma. One character absolutely puts *P. Ruffordi* out of the question,— it contains traumatic resin ducts,— which as pointed out above, were not present here. It cannot be placed with *Pinus Nathorsti* (15), which had thick-walled, unpitted parenchyma around the resin canals and lacked tangential pitting, or with *Protopiceoxylon antiquius* Gothan (19). That species had thick-walled ray parenchyma, thick-walled epithelium around the resin canals, three to four pits to each crossfield on the lateral walls of the rays, and lacked tangential pitting,— features diametrically opposed to those of our fossil. Accordingly, our specimen cannot be identified with any previously described. In view of the fact that the leaves were borne on the main axis exclusively, rather than on short shoots, it may appropriately be called *Pityoxylon foliosum*. The only other forms with such leaves are *Pinus protoscleropitys* and *Prepinus*. With the former it cannot be identified because that form had such abundant short shoots that it would be impossible to miss them, and further it had ray tracheides. As suggested above, it may very probably be the wood of *Prepinus*.

Pityoxylon anomalum n. sp.

The third type of Pityoxylon differs from either of those previously described, though similar to *P. foliosum*. Figure *f*, Plate **3**, shows the general topography of the stem. The annual rings are narrow and indistinct. Resin ducts are present, extending in two planes, but as is evident from a comparison of Figures *b* and *e*, Plate **3**,— equally enlarged — they are much less frequent in this specimen than in the former. A further difference is that there is but one row in the first annual ring; this row occurs in the primary wood. Figure *a*, Plate **4**, shows the character of the ducts. They are surrounded by a large mass of epithelium, which is completely filled with resin. This feature is best brought out in the longitudinal sections (Figures *b*, *f*, and *g*). The cells of this jacket are fairly thin-walled, and very heavily pitted, which doubtless accounts for the abundant tyloses, which are very thick-walled. As a rule there is but a single canal in each cluster of parenchyma,— rarely there are two.

The tracheides are badly collapsed, and the lumen usually completely obliterated. At times, however, in the better preserved regions, the characteristics of the pitting may be made out. In the lower part of Figure *g*, for example, a single row of pores may be ob-

served. This is universally the case,— the tracheides being too narrow to accommodate a double series; in no case was the preservation sufficiently good to make out the bars of Sanio. Tangential pitting also is present, rather infrequently, on the face of the summer wood.

The rays are of two sorts,— linear and fusiform. Their highly resinous condition obscures the pitting, which in favorable localities is seen to be piciform. The pores are one to each crossfield, circular on the wall of the tracheide, and elliptical on that of the ray. In no case was there evidence of pit fusion.

The section photographed for Figure *f*, Plate **3**, was cut at the region of the exit of a brachyblast. Figure *e*, Plate **4**, shows its structure in cross section. The enlargement is the same as that of Figure *c*, which represents *Pinus protoscleropitys*. In the case of both, the short shoots are much larger than those of living pines, and in the medulla of each, there are aggregations of sclerified tissue similar to that of the main axis.

The affinities of this specimen are rather difficult to determine. The presence of short shoots and the absence of wood parenchyma relegate it definitely to *Pinus*. Further it is impossible to go, for it has the characteristics of neither a hard nor a soft pine exclusively,— the presence of tangential pitting and single row of resin canals excludes the former, and the presence of stone cells excludes the latter. As regards other fossil forms, its affinities are equally indefinite. It lacks the ray tracheides of *Pinus scituatensiformis*, *P. succinifera* or *P. protoscleropitys*, and the tracheary tyloses and toothed ray parenchyma of *Pinites Ruffordi;* unlike *Protopiceoxylon antiquius* and *Pinus Nathorsti*, there is tangential pitting. On the other hand, *Pityoxylon statenense* has no sclerenchyma in the pith, and *P. foliosum* has abundant leaf traces. Granted that *Prepinus* really belongs with *Leptostrobus* this cannot be the wood of *Prepinus*, because it has no primary leaves. In other characteristics, its general resemblance to *Prepinus* is quite striking. The woods look alike,— both have stone cells in the pith, resinous rays, piciform ray pitting,— further both have numerous small crystals,— a feature of neither of the other specimens.

In view of these apparent points of difference from other forms, it is suggested that this fossil be called *Pityoxylon anomalum*.

SUMMARY.

1. The Pityoxyla of Cliffwood, New Jersey, include the following previously undescribed varieties:
   (1) *Pinus protoscleropitys*,— probably the earliest form with all the characters of a modern hard pine, yet retaining certain ancestral features, as the association of primary and fascicular leaves, the latter borne on brachyblasts subtended by a foliar trace.
   (2) *Pityoxylon foliosum*,— possibly the wood of *Prepinus*, with all its leaves borne directly on the main axis, and presenting mingled characteristics now confined exclusively to either hard or soft pines.
   (3) *Pityoxylon anomalum*,— with ligneous features extremely like those of *Prepinus*, yet with all its leaves borne on short shoots.
2. The absence of tangential pitting in the first described *Pityoxylon*, and its presence in the other two, confirm the conclusions of Jeffrey and Chrysler that tangential pitting is a primitive feature now lost in the more highly specialized hard pines.
3. The absence of evidence confirming the origin of ray tracheides from vertical tracheides of the wood, renders it unlikely that this hypothesis is correct.
4. The occurrence of a completely differentiated hard pine as far back as the Middle Cretaceous is an argument for the great geological antiquity of the pines as such.

In conclusion, I wish to thank Professor E. C. Jeffrey for all the material used in this investigation, for an opportunity to examine sections of *Prepinus*, and for his helpful advice throughout the course of the work. To Professor I. W. Bailey, I am indebted for opportunity to study sections of *Pinus scituatensiformis*, and to Mr. E. W. Sinnott for sections of various living pines.

Literature.

Jeffrey, E. C.
(1) The Comparative Anatomy and Phylogeny of the Coniferales. Part 2. The Abietineae. Mem. Boston soc. nat. hist., vol. 6, no. 1.

Jeffrey, E. C.
(2) The Comparative Anatomy and Phylogeny of the Coniferales. Part 1. The Genus *Sequoia*. Mem. Boston soc. nat. hist., vol. 5, no. 5.

Jeffrey, E. C.
(3) The *Araucarioxylon* Type. Proc. Amer. Acad. Arts and Sciences, vol. 48, no. 13.

Conwentz, H.
(4) Monog. d. Balt. Bernsteinbaume. Danzig, 1890.

Bailey, I. W.
(5) Cretaceous *Pityoxylon* with Marginal Tracheides. Annals of Botany, vol. XXV, no. xcviii, April, 1911.

Gerry, E.
(6) Bars of Sanio in Coniferales. Annals of Botany, vol. xxiv, no. 93, Jan., 1910.

Jeffrey, E. C.
(7) A new Araucarian Genus from the Triassic. Proc. Boston soc. nat. hist. vol. 34, no. 9, p. 325–332, pls. 31, 32.

Fontaine,
(8) The Potomac or Younger Mesozoic Flora, Monog. U. S. Geol. Survey, xv.

Jeffrey, E. C.
(9) Structure of the Leaf in Cretaceous Pines. Annals of Botany, vol. XXII, no. LXXXVI, April, 1908.

Stopes, M. C. and Kershaw, E. M.
(10) Anatomy of Cretaceous Pine Leaves. Annals of Botany, vol. XXIX, no. 94, April, 1910.

Jeffrey, E. C. and Chrysler, M. A.
(11) Cretaceous *Pityoxyla*. Bot. Gaz., vol. XLII, July, 1906, pp. 1–15.

Seward, A. C.
(12) New Species Conifer, *Pinites Ruffordi*, from English Wealden Formation. Jour. Linn. Soc. vol. 32, p. 417.

Thompson, W. P.
(13) The Origin of Ray Tracheides in Conifers. Bot. Gaz., vol. 50, no. 2, Aug., 1910, pp. 101–106.

Penhallow, D. P.
(14) Manual of North American Gymnosperms, Boston, 1907.
Conwentz, H.
(15) Untersuchungen u. foss. Hoelz. Schwedens, Konig. Svenska Vet. Ak. Handl. Bd. 24, no. 13, 1892.
Jeffrey, E. C.
(16) A New *Prepinus* from Martha's Vineyard, Proc. Boston Soc. Nat. Hist. vol. 34, no. 10, p. 333–338, pl. 32.
Seward, A. C.
(17) Fossil Plants of the Wealden, pt. 2. British Museum Catalogs.
Hollick, A.
(18) Cretaceous Marls of Cliffwood, New Jersey.
Gothan, W.
(19) Die fossile Hoelzreste von Spitzbergen. Kongl. Svenska Vet. Ak. Handl. Bd. 45, no. 8.

DESCRIPTION OF PLATES.

PLATE 1.

a. *Pinus protoscleropitys*, transverse section of wood. × 40.
b. Same, transverse section near pith. × 15.
c. Same, radial section. × 40.
d. Same. × 80.
e. Same, tangential section of wood. × 40.
f. Same, showing leaf trace. × 60.

PLATE 2.

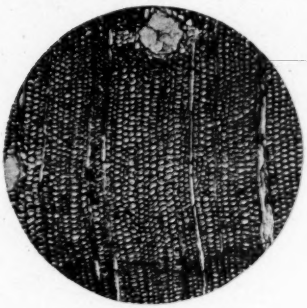
a. Same, radial section, showing ray pitting. × 150.
b. Same. × 500.
c. Same, showing ray tracheides. × 150.
d. Same. × 500.
e. Same, showing teeth in tracheide. × 500.
f. Same, showing radial pitting of tracheide. × 600.

PLATE 3.

a. *Pityoxylon foliosum*, transverse section of wood. × 40.
b. Same, transverse section at pith. × 12.
c. Same, radial section of wood. × 40.
d. Same, radial section at pith. × 12.
e. Same, tangential section of wood. × 40.
f. *Pityoxylon anomalum*, transverse section at pith. × 12.

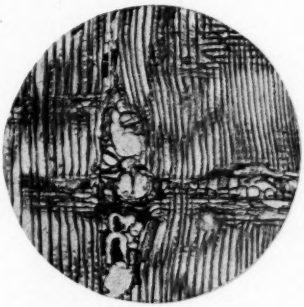
PLATE 4.

a. Same, transverse section of wood. × 40.
b. Same, tangential section of wood. × 40.
c. *Pinus protoscleropitys*, tangential section including short shoot. × 15.
d. Same, including leaf trace and short shoot, cut nearer pith. × 12.
e. *Pityoxylon anomalum*, tangential section, including short shoot. × 15.
f. Same, radial section of wood. × 40.
g. Same. × 80.



a

b



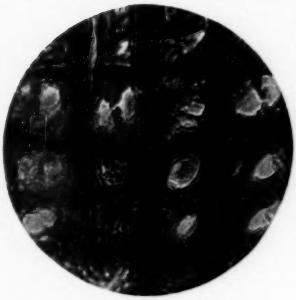
c

d

e

f

a

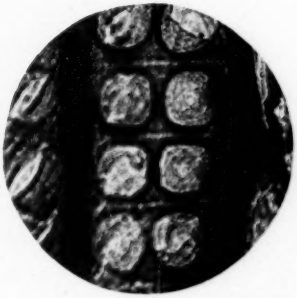


b

c

d

e

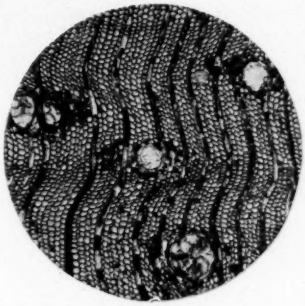


f

U of M

HELIOTYPE CO., BOSTON

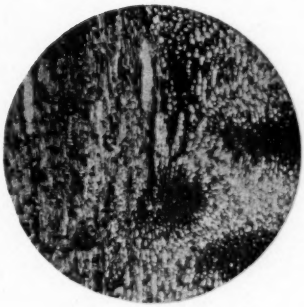
Mau



a

b

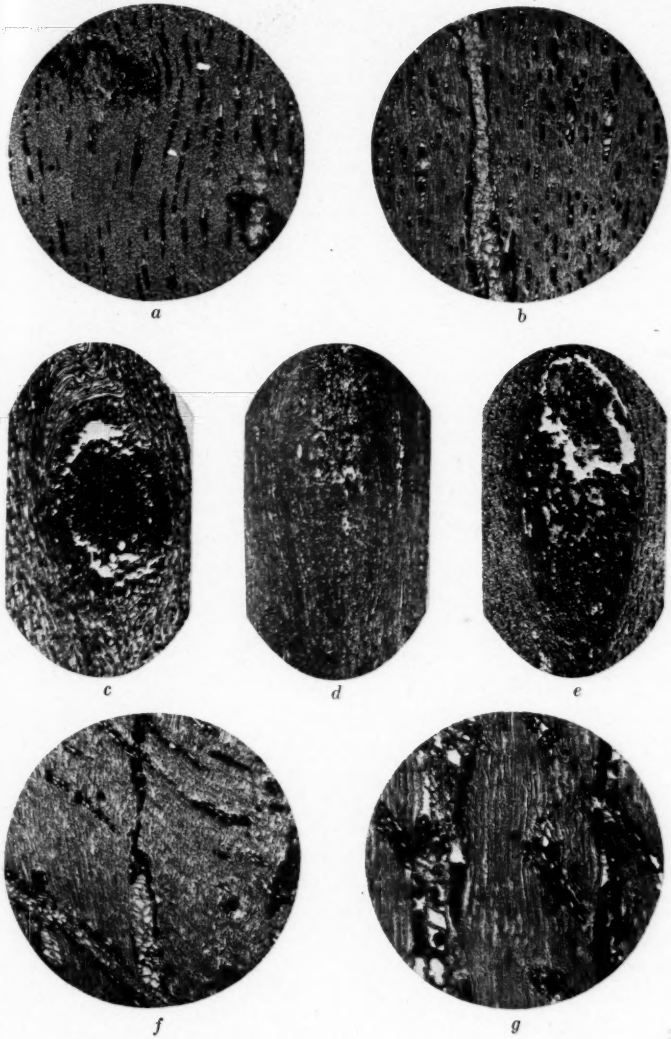
c



d

e

f


a
b
c
d
e
f
g